Football

If you measure popularity in terms of fan following, then football must surely be one of America's favorite sports. Played at the mid school, high school, collegiate, and professional levels, football draws players and viewers from all areas of society. Many student athletes look to the sport as a ticket to higher education. So, what is the story here? What's happening in the game? Consideration of a complex game like football can only be done by breaking the game down into component parts and asking basic questions. In studying this sport we will look at the following questions which are critical to the game:

- Why are defensive linemen always big, heavy guys?
- Why is a smaller guy moving fast hard to stop?
- Why must be a passed football spiral?
- Why is a three point stance so stable?

Question 1: *Why are defensive linemen always big, heavy guys?*

Introduction

Even an observer with no knowledge of the game of football would note that the defensive line is made up of BIG GUYS. The implication of that observation is that size is a unique qualification for success on the defensive line. Why is that true? The answer lies to examination of the job of the defense in a football game. One old cheer illuminates this point. It goes, 'Push 'em back, push 'em back, way back!' And that is the point of defense. Their job is to keep the offensive from advancing the ball down the field. To do that they must stop any penetration of the line of scrimmage. How do you stop a runner from penetrating the line? Why you 'push' them back! In other words, you apply force to ball carriers to stop their forward progress. We'll use the following experiment to demonstrate how the size of an applied force is related to the mass of the object applying the force.

Equipment Needed

1. Spring balances (measuring in newtons or lbs.)
2. String
3. Weights

Procedure

1. Set up the equipment so that a small weight from the set is tied to an appropriate spring balance. The connection should allow the weight to be pulled by the spring balance along a flat surface.
2. Measure the amount of force needed to just start the weight moving and record the force and the mass on Table 1 below.
3. Repeat the procedure for four successively larger weights.

Table 1

Mass of weight	Force needed to move
1)	
2)	
3)	
4)	
5)	

Analysis/ Questions

1. Graph the relationship of force and mass.
2. Examining your data table and the graph, what conclusion can you reach regarding mass and force?
3. Explain why a large, massive lineman would be harder to move past and would be better able to apply the force necessary to stop ball carriers from the offense.

Question 2: *Why is a smaller guy moving fast hard to stop?*

Introduction

Another observation that can be made about football is that offensive running backs are often smaller guys (than the defensive or offensive linemen) but are virtually always *fast* guys. At least they are capable of accelerating rapidly off the line of scrimmage. If they have good balance and body control, they are really hard to tackle. The reason lies in the second component of force production: acceleration. These players need to get past defensive players and they rely on a relationship that Sir Isaac Newton identified in the seventeen century. That is, the force produced by an object is equal to the object's mass multiplied by it's acceleration. Stated as an equation this is: $\mathbf{F = m * a}$ where F is the force, m is the mass, and a is the acceleration. Since acceleration is defined as a change in velocity during an elapsed time, you can look at force in a related way: $\mathbf{F = m (v_f - v_i)/t}$ where v_f is final velocity (= 0 in this case) and v_i is initial velocity (= the runner's speed when he is tackled). So, in order to tackle a fast-moving runner, the defensive player must apply enough force to change the runner's velocity to zero. If the runner in a quick accelerated this can amount to a lot of force. Let's do an experiment to show how an object is harder to stop as it moves faster.

Equipment Needed

1. CBL unit
2. Force probe
3. Physics car
4. String
5. TI82 with program Force Real Time entered
6. Weights and weight holder

Set Up

1. Tie piece of string to one end of physics car.
2. Attach other end of string to weight holder.
3. Place car on table 20 cm from the edge of the table with weight holder over the edge.
4. Have one student hold the force probe at the table edge so that the car will be stopped by the probe as the weight pulls the car of the table.
5. Have another student hold the car in place until the program is started.
6. Connect the force probe to the CBL unit and connect the TI82 to the CBL unit.
7. Turn on the TI82 and the CBL unit. Begin the program Force Real Time. Zero the force probe.
8. Put a small weight on the weight holder so that the car moves forward when released.
9. Be sure to time the release of the car with the start of the force program.
10. Use the TRACE function to determine the maximum force delivered to the probe. Record the values for the weight on the holder and the maximum force on the table below.
11. Repeat these steps with increasing weights until you have five trial runs.

Weight	Maximum force
1)	
2)	
3)	
4)	
5)	

Analysis/ Questions

1. Describe how the speed of the car changed as the weight on the holder increased.
2. How did the maximum force change as the weight on the holder increase?
3. What do you conclude about stopping a moving object?
4. How does this conclusion relate to stopping a runner in football?

Question 3: *Why must a passed football spiral?*

Introduction

If you ask someone what the most obvious difference between football and other ball games is they would probably say the shape of the ball itself. A football does have a unique shape; and because it does the football is more difficult to throw than a spherical ball. Any quarterback wants the football to follow the same parabolic flight path of a spherical ball. That path is simply easier to predict and execute for both thrower and catcher. A properly thrown football will do just that. But, the key to getting the flight perfect is a spin the football about its long axis. The following exercise will demonstrate the need for the rotation.

Equipment Needed

1. Football
2. Video camera
3. VCP with single frame advance

Procedure

1. Videotape a student who knows how to throw the football throwing it. Start with the laces of the ball facing the camera.
2. Videotape a student who can't throw the ball trying to throw it. Be sure to get a real novice so that the ball tumbles.

Analysis/ Questions

1. Watch the video of the good thrower frame by frame. Pay close attention to the rotating of the laces about the central axis.
2. Watch the video of the tumbling throw. Do you see any rotation? Around what axis does the ball tumble?
3. Research why the football needs to rotate around the longitudinal axis to stay on a true parabolic path. Have the class write an explanation of this phenomenon.

Question 4: *Why is a three-point stance so stable?*

Introduction

A quick glance at the line of scrimmage before the ball is snapped shows that the linemen for both the offense and defense are often in a three point stance. That is, they have both feet and one hand on the ground in preparation for the play to begin. Why do they take this position? To answer that question we need to recall that the job of linemen is to stop penetration of the line on both sides. We have already demonstrated that one way linemen resist movement by other players across the line is their massive size. Another factor which helps them to be 'immovable' objects is the stability of their stance.
We define stability as the ability to resist a change in body position when acted on by an outside force. In order to examine the factors which effect stability, we need to define and understand the concepts of center of gravity and base of support. Physically, center of gravity can be understood as the point about which the object's weight is balanced. Base of support is the area enclosed by the edges of the body parts in contact with the supporting surface. An examination of the relationship of center of gravity to base of support will give us insight into the stability of the three-point stance. First, let's look at center of gravity.

Equipment Needed: Part 1

1. Several small pieces of cardboard or poster board in various shapes
2. Modeling clay
3. Sharpened pencils

Procedure: Part 1

1. Place a piece of clay on the table.
2. Insert a pencil, erasure end down, into the clay so that the point is towards the ceiling.
3. Balance the shapes one by one on the pencil tip. When you get it to balance, mark the point on which the shape balances.

Analysis: Part 1

1. Look that the point marked for each of your shapes. How does this point relate to the geometric center of the shape?

2. Can you predict approximately where the center of gravity for the human body might be based on this experiment?

Equipment Needed: Part II

1. Chalk
2. String
3. Large washers

Procedure: Part II

1.For simplicity we will estimate the center of gravity of the human body as being around the waistline. In reality, the center is higher than waist level for most men and lower than waist level for most women. To approximately mark the center of gravity we will tie a string around the waist of the students. Allow about two feet of string to dangle down.
2. Tie a washer to the end of the string so that a plumb line is established.
3. Have the students work in pairs. Give each pair a piece of chalk.
4. For each position listed in the chart below the students need to mark the area of the base of support on the floor with the chalk and draw this on the chart. Determine whether the center of gravity is inside the base area and record this on the chart. Finally the second student will attempt to topple the first student. Record how difficult this was from the point of view of the student attempting to stay still.

Position	Base of support	Center of gravity	Ease of toppling
Stand on one foot			
Stand straight up on two			
Stand on two feet leaning forward as much as possible			

Three-point stance

Four-point stance

Analysis: Part II

1. Which position offered the greatest stability?
2. What relationship did you see between center of gravity, base of support, and stability?
3. Why do linemen take a three point rather than a four-point stance?